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STATE OF THE ART OF DEVICES FOR REDUCING ENERGY LOSSES FROM FLUE STACK GASES

JOHNS MANVILLE CORPORATION
RESEARCH & DEVELOPMENT CENTER
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DENVER, COLORADO 80217

15 January 1979

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Prepared for:
USA Facilities Engineering Support Agency
Technology Support Division
Fort Belvoir, VA 22060

This report contains information of a general nature. Refer to DAEN-FEU Technical Note No. 78-16 providing guidance for use of devices designed to reduce flue stack gas energy losses.

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The current state of the art for devices for saving energy that would be lost in flue stack gases has been evaluated by means of market and literature surveys. These surveys have included conservations with members of organizations known to have been involved in device evaluation programs. In addition many companies have worked as consultants to these organizations.

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I. SUMMARY

Fuel fired furnaces and boilers produce heated combustion gases that are released to the atmosphere through vents or flues. When a furnace is off, natural draft in the vent causes air from the furnace room to escape up the stack. In situations where the combustion air comes from heated areas of the building, considerable energy is lost that must be made up by the furnace. It is estimated that up to 25 percent of the heating value of the fuel is lost up the stack during main burner operation.

Several devices are available in the market place which reduce these stack gas losses. Automatic Vent Dampers (AVD's) close when the burner is off to prevent the escape of stack gases. AVD's open when the burner is on so the furnace operates in its normal mode. A Vent Restrictor (VR) has the same basic purpose as an AVD and consists of a blast gate that is inserted into the flue to effectively reduce its size and slow the exit of conditioned air. A VR has energy saving potential when the burner is on or off. Supply of outside or unconditioned air for combustion also prevents the escape of building conditioned air and results in energy savings potential.

Furnace derating is a process of reducing the output of a furnace or boiler so as to better match the heat load of the building in which it is functioning. This improves the cyclic efficiency of the furnace and results in energy savings. Derating is best accomplished by using smaller diameter burner orifices and is applicable to gas or oil furnaces. Best energy savings are obtained when derating is coupled with combustion air adjustments that minimize the excess air.

Intermittent Ignition Devices (IID's) are designed to replace standing pilots in gas burning appliances. Several types of these devices are available for retrofit and show a great deal of maturity in their development because of their use in Original Equipment Manufacture (OEM) equipment.

Flue Heat Extractors (FHE's) and Extended Draft Hoods (EDH's) are related types of equipment that have been added to this study for the sake of completeness. FHE's and EDH's act like heat exchangers on the flue and extract heat from flue gas.

Table 1 lists energy savings expressed as a percentage of the total space heating requirements as obtained from several studies. Table 1 also lists average costs for each device including estimates of installation charges.

TABLE 1

COMPARISON OF ENERGY SAVINGS AND COSTS OF VARIOUS ENERGY SAVING DEVICES
AND COMBINATIONS OF DEVICES FROM SEVERAL SOURCES

DEVICE	ENERGY SAVING AS A PERCENTAGE OF THE TOTAL SPACE HEATING REQUIREMENTS									TOTAL
	SHEIP (1977-1978)	MCGC (1975-1976)	MCGC (1976-1977)	CPSL (1977-1978)	ADL (Gas)	BONNIE (Oil)	WALDEN (Oil)	COST (dollars)		
								UNIT	INSTALLATION	
AVD	- 1.5-24.9	23.6	25.6	5.5	8.0	11.0-13.0	---	140	70	210
VR	5.1-20.7	20.9	18.3	5.0	---	---	---	16	50	66
IID	-13.1- 5.0	3.58	2.2	2.0	3.0	5.0- 6.0	---	70	50	120
Derate (Fuel & CA)	7.0-14.8	9.9	13.8	10.0	---	8.0-15.7	7.8	10	96	106
Derate (Fuel Only)	1.1- 4.3	---	----	----	4.0	2.5- 5.0	4.7	2	96	98
Outside Air	- 0.7- 5.7	---	----	----	---	---	---	30	25	55
AVD + IID	7.9-13.3	---	----	----	11.1	---	---	190	70	260
Derate (F+A) + IID	12.6-21.0	---	15.9	----	---	---	---	80	110	190
Derate (F+A) + VR	7.8-26.1	27.8	25.4	----	---	---	---	20	100	120

F = Fuel CA = Combustion Air

AVD's, VR's, IID's, Derating, FHE's, and EDH's require conscientious installation by a qualified person familiar with heating and ventilating systems in order to function properly. Improper installation of AVD's for gas furnaces, VR's, FHE's, EDH's, or poor workmanship in derating can result in increased risk of a failure of these devices and potential health hazards can result. AVD's for oil furnaces of certain manufacturer are considered safe under proper installation. IID's present less chance of a hazardous failure than other devices. VR's are simple additions to a furnace that once are operating properly should continue to do so unless they are tampered with. Supply of outside air should not require a building permit under most codes as it does not consist of a major change in an existing appliance.

Enough data is available and in the process of being developed that additional testing by the Corps of Engineers is not recommended. To do so would result in a duplication of effort. It is suggested that a future Task under this contract be structured as a supplemental contract to update the Army on the progress of continuing evaluation programs and the status of code and standards requirements. Information that is in the process of being gathered by other organizations would provide the basis for a more pointed project. It is suggested as part of a follow-up contract that this information be used to provide a detailed outline to Army facilities of how each of the major parameters

affecting the economics of these devices can be incorporated in energy conservation retrofit planning.

II. INTRODUCTION

On February 6, 1978, Johns-Manville Sales Corporation was engaged under Task Order No. 1 of Contract Number DAAK 70-78-D-0002 by the United States Army Facilities Engineering Support Agency (FESA) of the Corps of Engineers to study the State of the Art of devices for saving energy that would be lost in flue gases discharged up the stack.

The current State of the Art of devices for saving energy that would be lost in flue stack gases has been evaluated by means of Market and Literature Surveys. These surveys have included conversations with members of organizations known to be involved in device evaluation programs.

Specific devices which have been studied are: automatic vent dampers, flue or vent flow restrictors, intermittent ignition pilots, two-stage fuel input valves, smaller diameter burner orifices, and supply of outside air for furnace combustion. Devices have been evaluated that could apply to operation of both gas and oil furnaces ranging in size from the smallest domestic units to 1,000,000 BTU/hour commercial units. The major emphasis

of this State of the Art study has been directed at devices which would be applied as retrofit items.

Information regarding energy savings, reliability, safety, status of specific codes and specifications, and steps required to obtain proper installation is presented as obtained from several sources. Costs of each device and cost to effect its proper installation are given. A list of references is provided to aid those seeking details of test or other evaluation programs.

In order to provide an easy reference for those seeking specific information about specific devices, information has been presented in chapter headings for each device. Within each chapter, the General Operation, Results of the Market Survey, Potential for Energy Savings, Safety Provisions, Code Restrictions and Approvals, and Cost of the particular device is presented. A summary chapter presents a comparison of advantages and disadvantages of each device as well as considering the potential of using two or more devices in combination to obtain the greatest cost effectiveness.

This is a State of the Art evaluation and has, therefore, relied heavily upon many sources for information. Appreciation is expressed to the American Gas Association, the Colorado Public Service Company, the Michigan Consolidated Gas Company, the Consumer Product Safety Commission, the National Bureau of

Standards, Oak Ridge National Laboratories, Honeywell Corporation, Underwriters' Laboratories, the American National Standards Institute, the National Fire Protection Association, and the Department of Energy, Conservation and Solar Energy Applications Consumer Products Programs for their willingness to share their wealth of knowledge and experience upon which this review is based. In addition, many companies have worked as consultants to the above organizations, these include: Battelle Memorial Institute, Detroit Testing Laboratories, Calspan Corporation, Arthur D. Little Consultants, Walden Laboratories, and Kearney Management Consultants. To all, thanks is expressed for their conscientious efforts.

III. AUTOMATIC VENT DAMPERS

A. GENERAL OPERATION

The typical COE building is heated by an oil or gas fired central furnace or boiler. During periods when the indoor temperature drops below the thermostat setting, the heater cycles on and off several times each hour as is required to replace heat lost from the building. Domestic gas furnaces of American Gas Association (AGA) certified design have measured laboratory and field efficiencies of 75 percent at full load steady state operation[1]. During furnace operation, stack energy losses amount to 25 percent of the heating value of the fuel. While the furnace is not operating between heating cycles, natural flue draft will cause air supplied to the furnace to go up the stack. A typical home furnace in Colorado will allow 30 cubic feet/minute of air to escape up a 5-inch vent with an 18-foot chimney when the outside temperature is 30°F and the indoor thermostat is set at 70°F. This means that air in a home with 1000 square feet of floor space and 8-foot ceilings would have to be replaced every 4 1/2 hours to replace non-operating stack gas losses[2]. Furnaces which draw combustion and stack dilution air from a heated space require up to 10 percent more fuel to heat the makeup air.

The purpose of an automatic vent damper (AVD) is to reduce the losses of this heated air when the furnace is not in operation. No savings are gained while the burner is operating except to the extent that an AVD reduces natural draft when it is in the open configuration. AVD dampers are classified as to their location and by the type of power used to operate them. A flue damper is one which is installed upstream from the point where dilution air enters the stack. A vent damper is installed downstream of the place where dilution air enters on gas furnaces and downstream of the barometric damper on an oil furnace[3]. Most AVD's on the market today are designed for use as their name implies, in the vent downstream of the draft hood.

Thermal dampers utilize thermal energy to activate their closure mechanism. When the furnace burner is not in operation, bimetallic louvers in a thermal damper close. The design of the louvers when closed offers 11 percent open space allowing some draft for the pilot light. When the burner is on, the bimetallic louvers bend back toward the walls of the vent providing more draft as the hot combustion products rise in the stack and cause the damper to open. Although thermal dampers are not currently available in the United States, they have been in use in Europe since as early as 1932. There are approximately 1.5 million thermally actuated dampers in operation in Europe, most of these having been installed since 1967[4]. Although some 11 accidents in which 12 deaths occurred are reported in West Germany with earlier

models of dampers, none have been reported since the current model went into production in 1967. Thermal dampers should only be considered in application to gas burning appliances as oil burners result in temperatures which are excessive. American Metal Products of Los Angeles, California has obtained a license from Werner Diermayer to produce and market these thermally actuated dampers in the United States[5]. The major advantages of thermal dampers are their relative low cost, simplicity of installation, and ability to operate without need for electrical circuitry. These advantages are of greatest interest for water heater appliances where electrical power is not an inherent part of the system.

Electrical dampers are the type currently being used in the United States. Electrical dampers are available that can be used as retrofit items for gas and oil burners.

Various types of actuation mechanisms are available. In some designs, an electric motor is utilized to rotate a metal plate in the flue. In other designs, a lever rotates the shaft which is actuated by a solenoid. All designs of electrical dampers incorporate limit switches which prevent the damper from closing when the burner is still on. In addition, some designs have a fail safe mechanism that opens the damper in the event of a power failure.

Several advantages are attributable to this type. Among them are: it allows a positive control sequence for on/off burner control and closure of the damper following the burning cycle can be rapid, thereby maximizing the effort to control energy losses. Electric dampers do require an external power source and since they are electro-mechanical in nature, are subject to failure of components.

Mechanical dampers use a form of mechanical energy to actuate closure of the device. Most such devices are of the gas pressure type. This type is operated by the gas pressure which passes the thermostat controlled main valve activating a lever mechanism that opens the damper. A diaphragm actuated valve is used in a return line to the burner to control the gas to the burner. The operation of such a mechanical system is illustrated in Figure 1. Mechanical dampers have the advantage of not requiring electrical controls. It does require a more complex installation and can, therefore, cost more than other types of dampers.

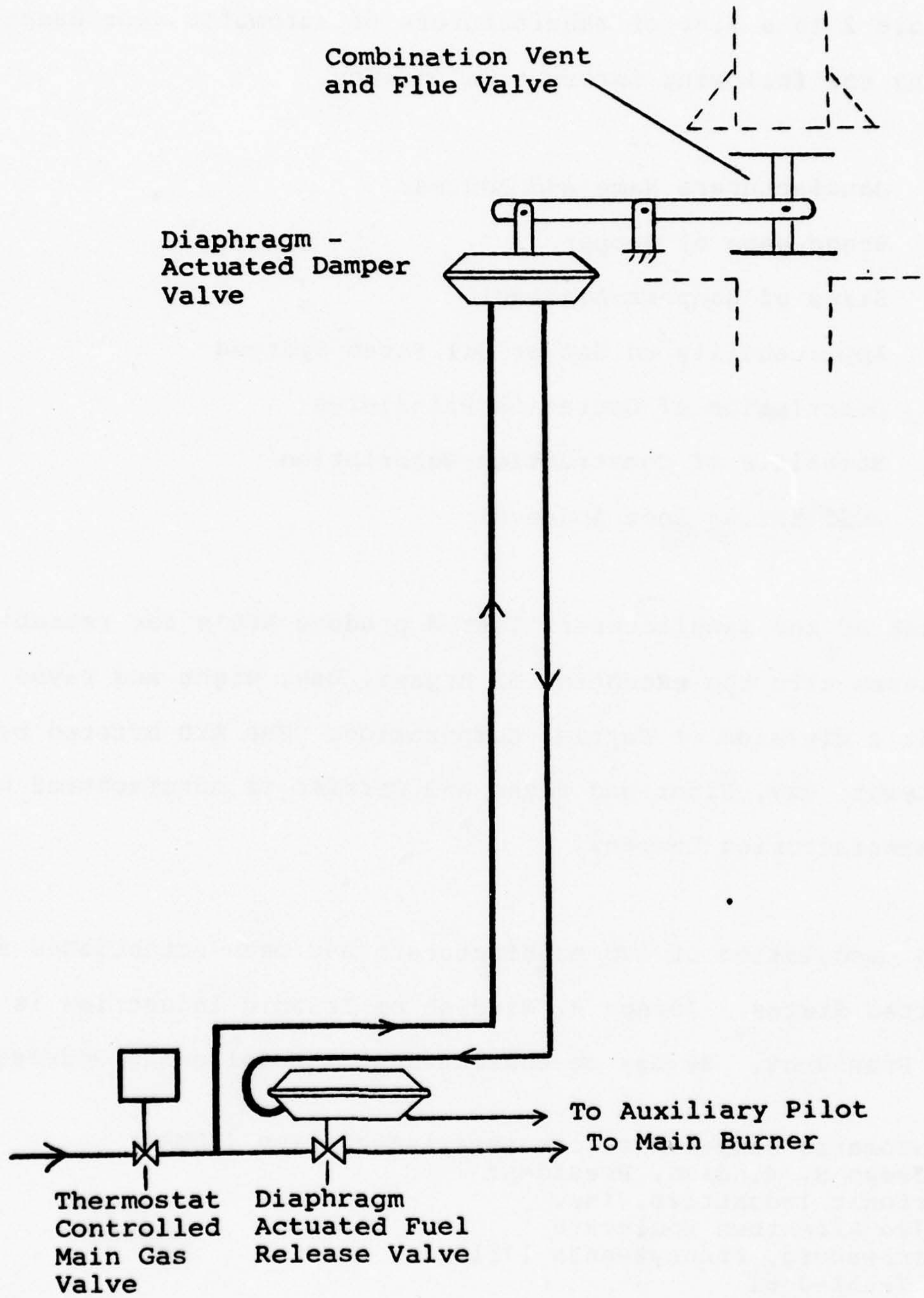

FIGURE 1. SCHEMATIC DIAGRAM OF
PRESSURE-ACTUATED VENT DAMPER
(Perfection Corporation)

B. MANUFACTURERS OF AVD'S

Table 2 is a list of manufacturers of automatic vent dampers including the following information on each.

1. Manufacturers Name and Address
2. Brand Name of Damper
3. Sizes of Dampers Available
4. Applicability to Gas or Oil Fired Systems
5. Description of Operation Principles
6. Materials of Construction Description
7. ANSI Z21.66 Code Approval

Most of the manufacturers listed produce AVD's for retrofit of furnaces with the exception of Bryant, Day, Night and Payne which is a division of Carrier Corporation. The AVD offered by both Bryant, Day, Night and Payne and Carrier is manufactured by Flair Manufacturing Company.

An association of AVD manufacturers has been established in the United States. Joseph H. Windish of Trionic Industries is the Acting President. He may be contacted at the following address:

Automatic Damper Manufacturers Association (ADMA)
Joseph H. Windish, President
Trionic Industries, Inc.
6720 Allentown Boulevard
Harrisburg, Pennsylvania 17112
717-652-0761

TABLE 2

MANUFACTURER IDENTIFICATION	BRAND NAME	FURNACE APPLICATION	SIZES AVAILABLE	CODE APPROVALS	DESCRIPTION
Ad Vant Industries 1030 West Germantown Pike Norristown, Pennsylvania 19401	Stack Master	Oil	4 to 12"	AGA ANSI Z21.66	Gear motor drives open and closed. Heavy gage galvanized steel casing, galvanized damper and steel shaft.
Cole-Sewell Corporation 2288 University Avenue St. Paul, Minnesota 55114 612-646-7873	DID NOT RESPOND TO MARKET SURVEY				
Diehl Manufacturing Company 3475 Gracelund Street Memphis, Tennessee 38116	DID NOT RESPOND TO MARKET SURVEY				
Dornbecil Furnace & Foundry Co. 33220 Lakeland Boulevard East Lake, Ohio 44094 216-946-1600	DID NOT RESPOND TO MARKET SURVEY				
Energy Vent, Inc. 423 Rita Street P. O. Box 14145 Dayton, Ohio 45404 513-222-7749		Gas	4 to 12" Standard - to 32" Special Order	AGA 12/19/77	Spring open, mechanical interlock prevents closure unless solenoid is energized. Continuously energized solenoid holds damper closed. Spun steel casing, aluminum damper, stainless steel shaft. Bimetal thermal safety switch opens damper when hot gases are present.
Flair Manufacturing Corporation 600 Old Willets Path Harppavge, LI, New York 11787 516-234-3600	Stack Pack	Oil Gas	4 to 12" 4 to 12"	UL AGA	Coiled spring drives damper open, gear motor drives damper closed and stalls during furnace standby. Cast iron case galvanized steel damper and steel shaft separate control unit with 2.5 minute delay used for oil applications.

TABLE 2 (Continued)

MANUFACTURER IDENTIFICATION	BRAND NAME	FURNACE APPLICATION	SIZES AVAILABLE	CODE APPROVALS	DESCRIPTION
Friedrick Air Conditioning and Refrigeration 4200 North Pan Am Express San Antonio, Texas 78295 512-225-2000	DID NOT RESPOND TO MARKET SURVEY				
National Fuel Saver, Inc. P. O. Box 222 Villanova, Pennsylvania 19085 215-525-3920	Fuelsaver	Oil Gas	5 to 10"		Green motor drives damper open and closed, 2 to 3 minute time delay for closure of oil unit. Tight fitting damper to damper case.
Gas Master Products, Inc. 2419 North Station Street Indianapolis, Indiana 46218	DID NOT RESPOND TO MARKET SURVEY				
Johnson Controls Penn Division 2221 Camden Court Oak Brook, Illinois 60521 312-654-4900	Mizer	Gas	4 to 7"	AGA	Used only in combination with IID using a redundant gas valve. Gear motor drives open and closed. Galvanized steel casing and damper with stainless steel shaft. Good retrofitting instructions.
Mechanical Engineering Savings Company Willoughby Hills, Ohio 44092		Gas			Electric heated element vaporizing fluid actuated.
TRD Corporation 7250 Commerce Drive Mentor, Ohio 44060 216-946-3800 John J. Preneau	Ventstopper	Gas			Gas pressure operation.

TABLE 2 (Continued)

MANUFACTURER IDENTIFICATION	BRAND NAME	FURNACE APPLICATION	SIZES AVAILABLE	CODE APPROVALS	DESCRIPTION
Save Fuel International 208 New Boston Road Woburn, Massachusetts 01801 617-933-8967	Safe Fuel Draft Control	Gas	4 to 8"		Spring positions damper to close and continuously energized solenoid opens damper. Has safety light that shows green when burner is on and damper is open. Chrome nickel plated case, aluminum on damper and aluminum shaft.
Save Fuel Corporation P. O. Box 670 Clarksdale, Mississippi 38614	Save Fuel formally Vent-O-Matic	Gas	4 to 8" 10 & 12"		Coiled spring opens, solenoid continuously energized to close, steel casing, aluminum damper, and stainless steel shaft.
Thermal Developments, Inc. Box 130A, RD 1 1625 North Nest End Boulevard Quakertown, Pennsylvania 18951	SAVE-A-THERM	Oil	5 to 10" Domestic 12 to 24" Commercial	UL Components	Spring loaded to normally open position, solenoid holds closed with power from independent 115 V source. Thermal switch gives 2 to 3 minute delay to close following burner turn off.
Trionic Industries, Inc. 6720 Allentown Boulevard Harrisburg, Pennsylvania 17112 717-652-0761 Robert F. Albrech	SENTINEL	Oil	5 to 10" 12, 14, 16, 18, 20, 22, & 24"	UL	Gear motor drives damper to open, micro switch and relay turns on burner circuit. Gear motor drives damper closed when burner circuit is de-energized. Cast aluminum casing, stainless steel damper and shaft.
William Steimen Manufacturing 29 East Halsey Road Parsippany, New Jersey 07054	DID NOT RESPOND TO MARKET SURVEY				
Utimatic Engineering Corporation HRL Division 200 West Central Street Natick, Massachusetts 01760	Heat Retention Control	Oil	6 to 10"		Electric actuated, motor driven closed, spring loaded open.

TABLE 2 (Continued)

MANUFACTURER IDENTIFICATION	BRAND NAME	FURNACE APPLICATION	SIZES AVAILABLE	CODE APPROVALS	DESCRIPTION
Carrier Carrier Parkway Syracuse, New York 13201	Chimney-Lock	Gas (OEM Only)	5 to 7"		Incorporates 45 second delay following burner shutoff to damper closure. Sold as OEM accessory. Made by Flair Corporation described above.
American Metal Products Company 6100 Bandini Boulevard Los Angeles, California 90040 Licensed Manufacturer of Werner Diermayer 1275 Panorama Drive Lafayette, California 94549 415-283-2609	Diermayer Damper	Gas	60 mm to 150 mm		Thermally actuated bimetal damper. Has 10 to 15 percent open area to allow escape of pilot light exhaust products and combustion flow of burner start up.

C. ENERGY SAVINGS

The potential for energy savings and the actual energy savings that are attributable to automatic vent dampers has been a controversial issue. Energy savings ranging to 50 percent are claimed by some manufacturers of AVD's. The principle source of backup information for manufacturer's claims is testimony given by Charles R. Montgomery, President of Michigan Consolidated Gas Company, before the United States Senate SubCommittee on Anti-Trust and Monopoly on August 26, 1972[6]. His report was based on tests of dampers placed in homes of employees of MCGC during the 1975-1976 winter. In addition, testimonials are offered by individual purchasers that show a range of energy savings from 2 percent to 42 percent. It is evident that the actual energy savings resulting from these devices depends upon many influencing factors. Among these are:

1. Damper Characteristics - design detail (closure rate, closure delay period, tightness of closure, etc.) and damper type (electrical, thermal, mechanical).

2. Building Conditions - building tightness to air exfiltration, chimney size, height and type, common venting of hot water heater, presence and extent of horizontal flue ducting, etc.

3. Weather - indoor to outdoor temperature differential, wind and other local weather patterns.

4. Furnace - degree of oversizing, cyclic characteristics, etc.

Several efforts have been made to incorporate major variables into computer simulation models of gas and oil furnaces. The National Bureau of Standards program, DEPAF (Design and Performance of Furnaces) prepared by Chi, Kelley, and Didion, simulates fossil-fuel-fired furnaces for residential heating systems[7]. Bonne of Honeywell and DeWerth of the AGA have evaluated several energy saving alternatives by dynamic computer simulation and laboratory testing[8]. Arthur D. Little, Inc. has developed a somewhat simplified model of a heating system; results are similar to those developed by others[9]. A comparison of the results of these several programs was presented by ADL to the Department of Energy and is given here in Table 3. The three far righthand columns of Table 3 give fuel savings expressed as millions of BTU/year, percent of the total space heating requirements, and the number of BTU's in thousands that are saved for each heating degree day each year. Fuel savings range from 6.4 percent to 18.6 percent of the total space heating load. Oil furnaces typically show lower energy savings partially because a delay is required in damper closure because of the inability to

obtain instantaneous fuel shutoff as is possible with gas furnaces.

TABLE 3

PREDICTIONS OF AUTOMATIC VENT DAMPER ENERGY SAVINGS*

SOURCE	LOCATION	DEGREE DAYS	INFILTRATION CHARGED TO VENT	TYPE	CAPACITY OVERSIZED	LOCATION	FUEL SAVINGS 10^6 BTU/YEAR	PERCENT	$\frac{10^3 \text{ BTU/YEAR}}{\text{DEGREE-DAYS}}$
CHI (NBS/DEPAF)	Washington, DC	(4,224)	70%	Gas Furnace	80%	Inside	9.3	11.1	2.2
	Atlanta, GA	(2,961)	70%	Gas Furnace	80%	Inside	7.3	12.9	2.5
(A)	Minneapolis, MN	(8,382)	70%	Gas Furnace	80%	Inside	17.6	14.4	2.1
	Washington, DC	(4,224)	70%	Oil Furnace	---	Inside	4.6	7.0	1.1
	Atlanta, GA	(2,961)	70%	Oil Furnace	---	Inside	3.5	8.0	1.2
	Minneapolis, MN	(8,382)	70%	Oil Furnace	---	Inside	8.5	8.0	1.0
BONNE, JANSSEN, NELSON, & TORBORG (1976) (HONEYWELL) (B)	Minneapolis, MN	(8,382)	50%	Gas Furnace	120,000 BTU/HR -50^oF Design Temp.	Inside	16.0	10.0	1.9
GABLE & KOENIG (CARRIER) (C)	Minneapolis, MN	(8,382)	---	Gas Furnace	125,000 BTU/HR	Inside	18.0	----	2.2
						Basement	11.0	----	1.3
	Syracuse, NY	(6,756)	---	Gas Furnace	100,000 BTU/HR	Inside	12.0	----	1.8
						Basement	8.0	----	1.2
	St. Louis, MO	(4,900)	---	Gas Furnace	100,000 BTU/HR	Inside	9.0	----	1.8
						Basement	6.0	----	1.2
	Atlanta, GA	(2,961)	---	Gas Furnace	80,000 BTU/HR	Inside	5.0	10.0	1.7
ADL (9)	NE/NC	(5,832)	70%	Gas Furnace	100,000	Inside/12 ft	11.0	9.3	1.9
			50%	Gas Furnace	BTU/HR	Basement/20 ft	8.1	6.9	1.4
	S/W	(2,832)	70%	Gas Furnace	100,000	Inside/12 ft	5.6	18.6	2.0
	NE/NC	(5,832)	70%	Oil Boiler	130,000 BTU/HR	Basement/20 ft	10.5	6.4	1.8
	NE/NC	(5,832)	70%	Oil Boiler	120,000 BTU/HR	Inside/12 ft	12.7	10.8	2.2

*No water heater damper or electric water.

Michigan Consolidated Gas has continued their field evaluation program through the 1976-1977 and 1977-1978 heating seasons. Today, some 50 utilities are participating in a comprehensive program being directed by the American Gas Association called Space Heating Efficiency Improvement Program (SHEIP). The first report of this program was made available in March 1978[10]. Energy savings are reported for the first winter season of this program (this program is scheduled to continue through the 1978-1979 winter) as ranging from -1.5 percent to 24.9 percent for the 122 automatic vent dampers reported. This wide range is not unexpected since it includes many geographical locations, furnace types, and chimney types. The largest savings are reported in the Detroit area where large 12-inch by 8-inch tile lined masonry chimneys are by far the majority. This contrasts with the average savings of 5.5 percent reported by the Colorado Public Service Company on their Denver located test homes. The homes used in Denver have a 5-inch galvanized metal stack that is 18 feet high. Local weather conditions also contribute to the differences reported in Denver and Detroit. Not only are the number of degree days greater in the Detroit vacinity, but the factor has an important effect on stack gas energy losses.

When the SHEIP study is completed, over 5000 homes across the country will have been involved. The goal of this program will be

to quantify specific energy saving results based on the most pertinent variables.

Although not enough information is yet available to be able to determine the energy saving for a given individual home or building, programs aimed at obtaining that information are in progress. The ranges of energy savings presented here can be looked at from the standpoint of guidelines for general areas of the country.

D. CODES AND STANDARDS

On November 11, 1977, the American National Standards Institute approved Standard Z21.66, "Automatic Vent Damper Devices for Use with Gas Fired Appliances". This standard is specifically oriented toward electrically actuated AVD's. In addition, draft copies of Standards for Thermally and Mechanically Actuated Dampers are out to ANSI committee members for review and comment. These draft standards will be discussed at up-coming ANSI meetings in April this year. It is currently expected that standards for Thermally and Mechanically Actuated Dampers will be approved sometime toward the end of 1978 or early in 1979. At this time, revisions are being considered to the National Fuel Gas Code ANSI Z2231.1 (NFPA No. 54) to allow installation of listed automatic vent dampers to existing appliances for the purpose of fuel conservation. Included in the Appendix of this revised code will

be a Recommended Procedure for Safety Inspection of An Existing Appliance Installation and a Recommended Procedure for Installing Electrically Operated Automatic Vent Damper Devices on Existing Appliances. Changes are also being proposed to the ANSI Z21.47 Central Furnace Standard and ANSI Z21.13 Boiler Standard to incorporate electric AVD's. Modifications to ANSI standards for Water Heaters, Z21.10, and Vented Room Heaters, Z21.11, are in the early stages of development, but include provisions for all three types of AVD's. Underwriters' Laboratories has been testing electrically actuated AVD's for oil fired heating equipment under their own standards (UL 378 Standard for Draft Equipment and UL 873 Standard for Temperature Indicating and Regulating Equipment). Both UL and AGA laboratories are currently testing devices to the ANSI Standard for Gas Appliances, ANSI Z21.66.

Standards of construction, performance, and installation procedures relating to electric AVD's applied to gas fired appliances equipped with a draft hood are the basic scope of ANSI Z21.66. This newly approved standard has the following significant provisions:

1. Size of vent is limited to 12 inches in diameter.

2. The damper must assume the open configuration in event of a power failure or device de-energization. A special

interlock may be provided that would prevent manual operation of the appliance when the damper is closed.

3. The minimum free venting area of vent gas passageway with the damper closed cannot be less than 10 percent of the total outlet venting area unless a redundant gas valve is specified.

4. A damper position indicator must be provided.

5. An interlock to prevent main burner firing unless the damper is in the fully open position must be provided.

6. A means that will prevent closing of the damper when the temperature in the vent indicates that the burner may be firing must be provided. This does not apply if a redundant gas valve is installed in the line to the main burner.

7. Devices must be installed by a "qualified" installer. A "qualified" installer is one who is engaged in and is reponsible for the installation of gas appliances and AVD devices, who is experienced in such work, familiar with precautions required, and has complied with all requirements of the authority having jurisdiction.

8. Instructions must be supplied by the manufacturer stating:

   a. Devices must be installed by a qualified installing agency.

   b. It is necessary to comply with local codes, or in their absence, the National Fuel Gas Code and the National Electrical Code.

   c. Step by step inspection and installation procedures in Exhibits A and B of ANSI Z21.66 must be followed.

   d. The device must be used only with gas fired appliances with draft hoods.

   e. The device must be installed downstream of the appliance draft hood and as close to the draft hood as practicable.

   f. The device must be located to serve only a single appliance.

To date, AGA Laboratories list five manufacturers with devices which have been tested and comply with ANSI Z21.66. Those approved with the model numbers of the approved devices are listed

Perigon Resources, Inc.
Models: AVD-4E, AVD-5E, AVD-6E, and ADV-8E

Flair Manufacturing
Models: SPG-4, SPG-5, SPG-6, and SPG-7

Energy Vent
Models: EV-4, EV-5, EV-6, EV-GC, and EV-(5,D)

Penn Division Johnson Controls
Models: Q16AA, Q16AB, Q16AC, Q16AD, 4-inch, 5-inch, 6-inch, and 7-inch

AdVant Industries, Inc.
Models: SMG-4, SMG-5, SMG-6, SMG-7, SMG-8, SMG-9, SMG-12, SMGX-4, SMGX-5, SMGX-6, SMGX-7, SMGX-8, SMGX-9, and SMGX-12

E. SAFETY

The Arthur D. Little report to the Department of Energy on Assessment of AVD's for Residential Heating Systems includes a chapter on safety. Included in the analysis is a fault free analysis and risk exposure analysis for thermally and electrically actuated devices. However, with the exception of thermal dampers safety experience in Europe, little actual data was available at the time of the ADL report[9]. The Consumer Product Safety Commission contracted with Calspan Corporation of Buffalo, New York to conduct tests solely related to the safety performance of several energy saving devices including ADV's[11]. The report of this work is in the draft stage, but is due to be published shortly. The work by Calspan represents a thorough reliability study in which 16 models of electrically actuated dampers, evenly divided between oil and gas appliations; 1 model

of a thermal damper; and 4 models of mechanical dampers were evaluated.

In general, since AVD's represent the addition of mechanisms in the control circuit, their introduction on a wide scale is certain to increase the number of accidents associated with heating appliances. "Given the best designs for Original Equipment Manufacture (OEM), this increase may be vanishingly small." There is a greater hazard potential in using dampers with gas fired equipment than oil fired equipment. Retrofit applications represent greatly increased possibilities for problems than OEM applications[11]. Calspan has conducted systematic inspection and safety analyses including formalized failure mechanisms, effect and correction/control analysis (FMECA), and fault free analysis procedures. Calspan's draft summary of the safety aspects of these devices considers four of the models tested for oil units as being acceptable. Calspan recommends some modifications to electrically actuated units for gas applications before considering them as being generally acceptable. The thermal damper was found suitable under controlled programs of marketing, installation, and testing. All mechanically actuated dampers were considered as being unsatisfactory from a safety standpoint.

The March 1978 issue of Consumer Reports carries their report of AVD's[12]. Although the few tests they have conducted show

energy savings enough to conclude that you can definitely save money, Consumer Reports cannot recommend their wholesale adoption because of concerns over safety aspects. The area of greatest concern regarding safety is how can you guarantee proper installation? Codes require installation be made by certified or qualified people. If a heating contractor cannot purchase an AVD unless he is able to show a certificate of his successful participation in a suitable installation course and he must certify each job, this coupled with a state or local building code official making an inspection of the finished installation would greatly enhance the expected safety record of AVD's. However, no one yet can offer a way to keep the ambitious do-it-yourselfer from obtaining and installing an AVD on his own. Arthur D. Little and others have suggested that only utilities be allowed to purchase and install such devices. Utility people could be properly trained and they already have extensive training in furnace operation and are familiar with furnaces in their locality as well as the building code requirements. Most major manufacturers offer training and certification programs for installers. The AGA under 3HEIP is in the process of preparing an extensive course. These are all steps in the right direction, but it seems that there will always be someone trying to save the $12.00 to $20.00/hour charged by someone with a valid license to install.

F. INSTALLATION

Installation of AVD's requires two basic steps. First, it requires a safety inspection of existing appliances. Second, it requires installation of the device itself including post-installation testing of its operation. ANSI Standard Z21.66 provides a step by step procedure to accomplish both of these objectives. Of course, Z21.66 applies only to electrically controlled dampers on gas furnaces. Instructions for thermal and mechanical dampers are available from manufacturers, but are only in draft form from ANSI.

G. COST

The economics of AVD's, that is their ability to bring a reasonable payback period, is primarily dependent upon: 1) actual energy savings, 2) cost of individual unit and its installation, and 3) the cost of energy saved. Arthur D. Little[9] and Kearney Management Consultants[13] have studied these variables and come up with the points shown in Table 3.

Table 4 represents costs obtained from several sources and represents the purchase cost of a 5-inch damper with an average installation time of 3 to 4 hours at a cost of $18.00/hour. Total cost should include the cost of a building permit. In Detroit, this cost is $26.00.

TABLE 4

COMPARISON OF INSTALLED COSTS FOR
VARIOUS TYPES OF DAMPERS

DEVICE	AVD (November 1977)	KEARNEY (1977)	JOHNS-MANVILLE (March 1978)
Electric (Gas)	$132.00	$145-$155	$172.00
Electric (Oil)	$155.00	$165-$175	$185.00
Thermal (gas)	$ 65.00	$ 65-$ 75	$ 60.00
Pressure	--	$155-$165	$190.00

IV. VENT RESTRICTORS

A. GENERAL OPERATION

A vent restrictor or a blast gate is a device designed to be placed in a vent to reduce the size of the vent. Reducing the effective diameter of the flue restricts the flow of air that can pass up the stack. Furnaces which are supplied by heated air for combustion will benefit in energy savings by reducing the amount of this heated air that can escape up the flue.

A vent restrictor can be applied to any combustion appliance that requires a vent. The purpose of the restrictor is to correct inefficiencies that have resulted from oversized flue pipes. Oversized vents have come about for similar reasons as oversized furnaces. A vent restrictor is a natural retrofit item, but its need is overcome in the OEM market by proper sizing of the flue.

A vent restrictor (VR) has the advantage of reducing energy losses even when the furnace burner is on. This contrasts with the AVD which saves energy only during the off cycle. The disadvantage is that VR's cannot be closed when the furnace is off.

A VR by its very nature is a simple device. There are no moving parts and it may consist of a sheet metal plate in a bracket that is easily inserted into the vent and then adjusted to obtain the desired restriction. Once the proper adjustment has been found, it can be rivited or welded into place.

3. MANUFACTURERS

VR's are normally made locally by a heating and ventilation contractor or a sheet metal fabricating firm. The Michigan Consolidated Gas Company began an evaluation of VR's during the 1975-1976 heating season and the results were so encouraging they have begun development of a design of their own. This MCGC VR will be a lightweight stainless steel blast gate. It will be fastened in place by a pop rivit to prevent modification of its position by a homeowner. This design is currently undergoing tests at the Detroit Testing Laboratories.

C. ENERGY SAVINGS

For most purposes, the same variables that influence the energy savings of an AVD will also effect a VR. A perfectly sized furnace would put out just enough heat by operating continuously to just keep up with the heat losses of the building while maintaining the desired indoor temperature. This, of course, would have to be true regardless of the outside temperature. This

implies a variable capacity furnace which is not available. A furnace that is greatly oversized may benefit more from an AVD than a VR. This is true since the burner off time would be high in comparison to the burner on time. On the other hand, a more properly sized furnace will tend to benefit more from a VR than an AVD since on time would be large in comparison to off time.

Energy saving results obtained from the MCGC program for the 1975-1976 and 1976-1977 seasons[14,15] are presented in Table 5. Results of an incomplete SHEIP coordinated by the AGA are also presented[10].

TABLE 5

ENERGY SAVING RESULTS OF SEVERAL
EVALUATION PROGRAMS ON VR's

STUDY	PERCENT OF SPACE HEATING SAVINGS
MCGC (1975-1976)	20.94%
MCGC (1976-1977)	18.3 %
MCGC (1977-1978)	Data Not Complete
SHEIP (1977-1978)	5.1 - 20.7%

The ranges of results presented are similar to those found for AVD's under the same evaluation programs. The energy savings reported by MCGC in the Detroit area are higher than can be expected in most areas. Generally when AVD's and VR's are compared on similar homes in the same geographical area, AVD's will provide 15 percent greater energy savings.

D. CODES AND STANDARDS

Fixed diameter flue restrictions are already certified in some areas and are being installed. ANSI is developing a standard for blast gates with special attention to installation procedures. However, one State Inspector said he would never allow anything to be placed in the flue. Another expert has drawn an analogy between the current conditions and when conversions were being made from coal to natural gas[13]. Then, it was often standard practice to use a blast gate. Today, of course, there are higher standards of safety and liability is a different matter. Therefore, it makes sense to have a qualified person follow a standard procedure to do this retrofit.

E. SAFETY

Several questions that are generally raised regarding safety of VR's are:

1. It is possible to produce a leak in the flue exhaust as a result of improper installation in sealing the new device.

2. Gases may accumulate in the flue due to excessive flue restriction.

Proper installation is something that should be done with the help of a qualified heating and ventilation contractor. All utilities participating in the SHEIP have the capability of making the proper installation of a flow restrictor.

Due to its simplicity, the dangers of installation of a VR are less than those associated with an AVD. MCGC found some evidence of corrosion on early blast gates since they were heavy and took sometime to heat up. For this reason, they have gone to a lighter weight gate made of stainless steel.

F. <u>INSTALLATION</u>

A Manual of Procedure for Area Reduction of Vent Connectors of Central Heating Appliances has been prepared by the AGA[10]. The procedure includes a safety inspection of the existing appliance. The sizing should be conducted during the summer season to account for the poorest draft condition, i.e., when the indoor-outdoor temperature differential is lowest. Under these conditions, the

restrictor is adjusted until spillage begins to occur at the draft hood. At this point, the restrictor is backed off slightly and the furnace is allowed to cool. After 30 minutes, the draft hood is again checked for spillage. If it still persists, the restrictor is adjusted until no spillage occurs. Following final adjustment, the restrictor is bolted, locked, rivited, or welded in place.

G. COST

VR's are simple and the one being designed by MCGC is expected to cost $16.00. Installation by a trained technician would take 1 1/2 to 2 hours and cost $18.00 to $36.00. In addition, the cost of a building permit in Detroit is $26.00, bringing the total cost to $60.00 to $78.00. It is entirely possible to greatly reduce this cost if many units are installed on a single contract. In this case, the total cost could be $25.00 to $40.00.

V. INTERMITTENT IGNITION DEVICES

A. GENERAL OPERATION

Intermittent Ignition Devices (IID's) conserve energy by eliminating the standing or continuous pilot light. The technology of IID's is well developed in comparison to AVD's and part of the reason is State Laws in California and New York require the elimination of standing pilots in OEM equipment. This experience on OEM furnaces coupled with 30 years of background with dryers, rooftop heaters, ranges, and commercial burners provides a good foundation for IID's.

Standard gas pilots surveyed in the SHEIP showed that they burned an average of 1.1 cubic feet of gas/hour. Some older conversion units required more than three times this amount. An IID can only save energy when the furnace is not operated and hence shows greater promise in areas where heating requirements are low.

There are four basic types of IID's available:

1. Direct Spark Ignition - an electrically generated spark is used to ignite the fuel/air mixture.

2. Recycling Pilot - the inactive pilot is restored by an electric spark. The pilot then ignites the fuel/air mixture.

3. Hot Surface - a metal surface is resistant heated to a high enough temperature to ignite the fuel/air mixture.

4. Piezo Spark - a mechanically generated spark ignites the fuel/air mixture.

Oil fired appliances already incorporate the direct spark IID; therefore, all comments of this section apply strictly to gas fuel appliances.

B. MANUFACTURERS

Table 6 is a summary of manufacturers who make IID's for retrofit. A list including OEM manufacturers is much larger and it is reasonable to expect the retrofit list will continue to grow as demand increases. Information included is manufacturer, type of ignition, description of unit including type of sensor, startup time, and 100 percent shutdown capability.

TABLE 6

MANUFACTURERS OF RETROFIT IID's

	TYPE	DESCRIPTION
DOMESTIC SIZE Carborundum	Piloted Glow Coil	Mercury Switch Sensor 40 second Startup No 100% Shutdown Capability
Penn-Baso	Piloted Spark	Flame Rectification Sensor 1 to 10 second Startup No 100% Shutdown Capability
White-Rogers	Piloted Spark	Mercury Switch Sensor 60 second Startup
Robert Shaw	Piloted Spark	Thermocouple Sensor 30 to 60 second Startup Has 100% Shutdown Capability
COMMERCIAL SIZE Honeywell	Direct Spark	Flame Rectification Sensor 11 second Startup Has 100% Shutdown Capability
Fenwall	Direct & Piloted Spark	Flame Rectification Sensor 7 second Startup Has 100% Shutdown Capability

C. ENERGY SAVINGS

The California Energy Resources Conservation and Development Commission authorized Arthur D. Little to study IID's for that State and the results were presented in April 1977[16]. This report describes IID's as not being an "energy bargain" even in the California climate, but it does conclude that energy savings can offset the original cost in that state if the following criteria are met.

1. The initial cost is in the neighborhood of $110.00 installed.
2. The furnace has more than a 7 year lifetime remaining.
3. The pilot rate is 800 BTU/hour or greater.

Results of Energy Saving studies are reproduced in Table 7.

TABLE 7

ENERGY CONSERVATION BY IID TESTED
BY SEVERAL GROUPS

STUDY	PERCENT OF SPACE HEATING HOOD CONSERVED
MCGC (1975-1976)	3.58%
MCGC (1976-1977)	2.2 %
SHEIP (1977-1978)	-13.1% - 5.0%
ADL	3.0 %

In geographical areas where the heating season is well defined, a viable alternative to an IID is turning off the pilot light during summer months. This step in itself will return the majority of energy savings anticipated from a retrofit IID.

D. SAFETY

The Calspan report to the Consumer Product Safety Commission concludes "as a class, the ignition systems evaluated reflected a maturity of development generally lacking in the automatic vent dampers. With the defined accepted limitations of service, all were considered to meet accepted standards of safety"[11]. This corresponds with the experience found in the ADL study in California in which no unsafe failures were reported from 7000 retrofit kit installations[16].

Installation of retrofit IID's appears to be technically feasible and safe when kit installations and inspections meet certain standards.

E. CODES AND STANDARDS

AVD's are certified by AGA laboratories to ANSI Standard Z21.20, Automatic Gas Ignition Systems and Components.

F. INSTALLATION

In order to obtain proper selection of the IID, the furnace make and model should be known, the pilot arrangement and gas valve inspected. Specific procedures are available from manufacturers and other sources[16].

G. COSTS

Installation of IID's with OEM equipment, increase furnace cost by $85.00 - $110.00. As may be expected, costs to obtain an effective retrofit will exceed this. Installations are reported by several utilities as taking a trained person from 1 1/2 to 2 hours. IID's can be purchased for $70.00 to $80.00, bringing the total cost to near $120.00

VI. FURNACE DERATING

A. GENERAL OPERATION

Derating of furnaces or boilers is performed to reduce the capacity of a unit that is larger than what is required. Furnace oversize has resulted from many causes over the years. Contractors have chosen to purposely install the "next larger size" to avoid callback problems. Addition of insulation, storm windows, and reducing air infiltration have effectively reduced the heat load. Derating can involve several changes to a furnace, but the major objective is to improve its effectiveness by bringing its capacity more nearly in line with the heating load.

Oil Furnaces have undergone extensive study over the past few years; all efforts being directed at improving their efficiency[17,18,19,20]. In a survey of oil furnace systems including hot water, warm air, and steam, Walden Laboratories found average oversizing was 168 percent[20]. Flue gas sensible heat losses can be reduced by either reducing the amount of excess air or lowering the flue gas temperature. When the burner is under standby, warm air flows through the system due to natural draft, cooling the heat exchanger and producing heat loss. Also,

natural draft losses occur at the barometric damper. These standby period losses can be reduced by minimizing off-cycle durations, thereby increasing burner on-time. The most effective way to accomplish this derating is by replacing the existing burner orifice with one of smaller diameter. This process also has the effect of reducing on-cycle losses because temperatures are lowered and heat loss past the heat exchanger is less.

Gas Furnaces benefit in a similar manner as oil burners and surveys by AGA, MCGC, and Colorado Public Service Company (CPSC) show ranges of oversizing from 157 to 240 percent.

For gas furnaces, the major ways of derating are 1) smaller diameter burner orifices, and 2) two-step input valves. These methods are designed to reduce the gas flow rate and gas pressure respectively. Studies have shown pressure control to be difficult and not economically desirable[14]. For this reason, AGA SHEIP activities are directed toward a smaller diameter orifice derate.

B. MANUFACTURERS

Manufacturers of derating equipment are numerous, some of which are listed below.

Anderson Brass Company
100 South Cambell Avenue
Detroit, Michigan 48209

Harper-Nyman Corporation
930 North York Road
Hinsdale, Illinois 60521

W. J. Schoenberger
P. O. Box 748
Waynesboro, Tennessee 38485

Conbraco Industries, Inc.
P. O. Box 247
Matthews, North Carolina 28105

Lincoln Brass Works
2051 12th Street
Detroit, Michigan 48216

In addition, different sizes of orifices can be purchased from most major furnace manufacturers or are available at heating and air conditioning supply houses.

C. ENERGY SAVINGS

Oil Furnaces in the New England area were retrofitted with smaller diameter orifices by Walden Laboratories under contract with the National Bureau of Standards (NBS). The average fuel savings on 25 units that were derated was 4.6 percent[20]. This excludes two steam systems which actually showed increased usage because the nozzles were too small. On units whose CO_2 concentration in the stack was either unchanged or increased by the nozzle size reduction, the average energy savings was greater at 7.8 percent. Following these encouraging results, NBS contracted with Ulrich Bonne of Honeywell to use this data combined with their computer model of combustion to come up with

energy savings for the New England area. The results of this computer work was published in 1976[19]. For New England with a distribution of 35.6 percent air, 44.0 percent water, and 20.4 percent steam, fuel savings were 5.2 percent for an average nozzle reduction of 29.4 percent. An important finding was that up to 8 percent fuel savings could be obtained if excess air was maintained constant. If the same nozzle size reduction could be obtained while reducing the excess air from 85.7 percent to 40 percent a 15.7 percent fuel savings would result. NBS has a continuing program to study the efficiency of oil burning furnaces and hopes of achieving better fuel savings are in the offing.

Gas Furnace field tests in Michigan and reports by SHEIP reveal energy savings for systems using smaller diameter orifices as listed in Table 8.

TABLE 8

ENERGY SAVINGS FOR GAS FURNACE DERATING BY USE OF SMALLER DIAMETER BURNER ORIFICES

STUDY	PERCENT OF SPACE HEATING SAVED
MCGC (1976-1977)	13.8
MCGC (1975-1976)	9.99
SHEIP (1977-1978) (Fuel Only)	1.1 - 4.3
SHEIP (1977-1978) (Fuel & Combustion Air)	7.0 - 14.8

The preliminary results of SHEIP show similar trends to those found by Bonne on oil furnaces. That is, it is important to control excess or combustion air. This was accomplished in the MCGC tests by providing a baffle at the furnace air intake[15].

D. CODES AND STANDARDS

Derating is a significant job reserved to trained people and since it is a major change to an existing household appliance, most building codes would require obtaining a permit and followup with an inspection. AGA has developed a Manual of Procedure for Field Derating of Central Heating Appliances.

E. SAFETY

The most serious concern for derating is reducing the stack temperature too low so as to produce condensate of flue products and induce corrosion of the vent and heat exchanger. This problem rests in the hands of the installer hence the need to have a qualified responsible workman.

The AGA has been conducting laboratory tests to determine the corrosion influence of derating. Two methods are used: 1) reduce fuel input while maintaining a constant stack CO_2 level, and 2) reduce fuel input while maintaining a constant steady state thermal efficiency. In either case, the condensation is greater.

Preliminary results indicate a slightly higher rate of corrosion for the constant CO_2 method as opposed to the constant thermal efficiency method.

F. INSTALLATION

The AGA has produced a detailed Manual of Procedure for Field Derating of Central Heating Appliances[10]. The procedure requires measurement of CO_2 in the flue implying special equipment and training. Another indispensable part of the derating process is calculation of the heater input requirement for a design condition. CPSC sizes a furnace retrofit based on a $-15^{o}F$ outside temperature and a $70^{o}F$ indoor temperature so that the furnace would just produce the heat loss of the house and then adds 10 percent capacity as a safety factor. Manufacturers recommend that gas furnaces not be derated by more than 70 percent in order to keep from lowering stack temperatures into the region which can cause corrosion problems.

G. COSTS

The cost of new burner orifices is generally small. MCGC reported $17.00 as an installed cost. However, a complete furnace derating involves a great deal more than that and includes a complete furnace safety check. CPSC charges up to $96.00 for this

service. Kearney Management Consultants estimates $90.00 to $100.00[13].

VII. OTHER DEVICES

A. OUTSIDE AIR SUPPLY

AVD's and VR's of the devices presented so far depend upon the use of conditioned or heated air to save energy. In many cases, furnaces may be located outside the building or in an unheated area such as a crawl space. For these situations, use of an AVD or VR is not sensible. In addition, because of the location of some furnaces or boilers, it is practical to supply the furnace with outside air for combustion. This can be accomplished by suppling an air duct to an isolated furnace room in the basement from an attic or other outside source. It is also possible to construct a simple air chamber surrounding a furnace air intake.

The AGA SHEIP has included some homes for evaluation to which outside air has been supplied to the furnace. Energy savings to date range from -0.7 to 5.7 percent[11].

Cold air entering a warm building through a metal duct may result in undesirable condensation on the exterior walls of the ducting. This is overcome by use of fiber glass insulated duct

that has a vapor barrier on the outside. Insulated ducts can help avoid cold spots near ductwork and reduce condensation. These duct materials certified to UL 181 are available from several manufacturers. It is also easier to install than metal which requires some fabrication work.

ASHRAE requires that for each 4000 BTU/hour of furnace capacity, one square inch of vent area be available. A 80,000 BTU/hour furnace would need a minimum of 20 square inches of vent area. This could be supplied by a 4-inch by 5-inch rectangular duct or a 5-inch diameter circular duct.

Approximate costs of circular flexible fiber glss air duct with vapor barrier facing are listed below:

DUCT DIAMETER (inches)	MATERIAL COST (Dollar/Linear Foot)
5	1.16
6	1.23
7	1.41
8	1.55
9	1.71
10	1.82
12	2.27
18	4.21

B. HEAT EXTRACTORS

Flue heat extractors (FHE's) come in many sizes and types and the list of suppliers seems to be growing on a daily basis. Their major purpose is to extract heat from combustion gas products in addition to that which is done by the furnace heat transfer surfaces.

Several types of FHE's can be categorized as air to air natural convection, air to air forced convection, and air to liquid radiator. A list of manufacturers of heat extractors is given in Table 9.

TABLE 9

FLUE GAS HEAT EXTRACTORS

SOURCE	TRADE NAME	TYPE	REMARKS
American Energy Conservation 105 Executive Park Louisville, Kentucky 40207	Therma-Corte Boilermate, Red Coat	Air/Water	For Use with Hot Water Boiler Systems; Unit Not Received.
Edmund Scientific Company 300 Edscorp Building Barrington, New Jersey 08007	Fuel Miser	Air/Air Forced Convection Air/Air Natural Convection	 Aluminum Fins that Attach to Outside of Vent Pipe.
Isothermics, Inc. P. O. Box 86 Augusta, New Jersey 07822	Air-O-Space	Air/Air Forced Convection Via Heat Pipes	
Lance International Division of McKey Corporation P. O. Box 1373 Manchester, Connecticut 06040	Lance Aire	Air/Air Forced Convection	Two Models.
Magic Heat Corporation (Formerly Calcinator Corp.) G-3084 East Hemphill Burton, Michigan 48529	Magic Heat	Air/Air Forced Convection	
Torrid Manufacturing Company 1248 Poplar Place South Seattle, Washington 98144	Torrid Air	Air/Air Forced Convection	

Many questions of safety have surrounded the use of FHE's. The Calspan report to the Consumer Product Safety Commission expressed two major concerns: 1) each of the units restricts the flow in the vent system, and 2) thermostatic controls are not sufficiently responsive to flue temperature[11]. The end result of these deficiencies is the production of increased spillage of combustion products at the draft hood and condensation of acidic combustion products within the vent system. The acidic combustion products are a result of the production of sulphur trioxide, carbon monoxide, and nitrogen oxides in the combustion process which form acids in combination with water; also a by product of combustion. This weakly acidic moisture causes a mildly agressive corrosive condition to metal flues. This problem is potentially overcome by use of more corrosion resistant flues of enamel lined steel or asbestos cement flues both of which have extensive building code approvals.

At the last ANSI meeting, interest was expressed in developing a standard for heat extractors. At the upcoming April meeting, a Task Group will be formed to begin drafting such a standard. It is likely that an approved standard is more than a year away.

C. EXTENDED DRAFT HOOD

An extended draft hood is designed to replace existing draft hoods on gas furnaces. It works to save energy in several ways. The furnace is derated in the process of a normal installation. Flue gases are slowed down through a baffle system and heat extracted is radiated into the room. Building Code Officials Code Administrators (BOCA) has approved its use as a venting system for heating plants[21]. Additionally, Detroit Testing Laboratory, Inc. has certified its compliance to ANSI 721.47, Sections 2.18.4 + 2.20[22]. However, Calspan gives this summary report of their safety tests: "Provided that the extended draft was modified by inclusion of a hole in the top of the baffle to relieve buildup of combustible gases and was installed under carefully controlled conditions by trained installers including adequate checks for venting, a reasonably safe installation could be made with this device. However, improper installation in the hands of the general public or without adequate checkout procedures could result in serious safety hazards"[11].

The extended draft hood is a patented device made and marketed under the name of:

Thrifty-Vent by R. S. R. Investments, Inc.
1701 South First Avenue
Maywood, Illinois 60155.

VIII. CONCLUSIONS

AVD's, VR's, IID's, Derating, Flue Heat Extractors and Extended Draft Hoods require conscientious installation by qualified persons in order to be considered safe for retrofit applications. Of these devices, IID's show the greatest maturity in development and present the least chance of a failure resulting in a hazardous condition. VR's, due to their simplicity also offer energy savings with limited risk, once a proper installation is made. Derating by use of smaller diameter orifices present similar low risk possibilities when proper sizing has been completed. Certain AVD's for oil burners are considered safe; whereas all AVD's for gas furnaces could benefit from some improvements. In general, heat extractors and extended draft hoods have received the most resistance to code and standard authorities. To date, no National Standards exist for these two types of products.

For Army purposes, the first step toward energy conservation by use of these devices is to determine the Local Building Code requirements. Average energy savings and installed cost estimates are presented in Table 10. Actual energy savings will vary depending upon many variables at a particular location. Average

savings are expressed as BTU's saved each year for each heating degree day. A viable alternative to an IID is simply turning off the pilot light during summer and relighting at the beginning of winter or fall. Supply of outside air to a furnace is a possible alternative to use of AVD's and VR's. Indeed, some furnaces are already supplied with outside air. Generally speaking, the combination of furnace derating by a smaller diameter orifice including adjustments to combustion air and a vent restrictor give the best cost return. Additionally, fresh air supplies should be considered where location of the furnace seems to make this alternative viable.

TABLE 10

AVERAGE ENERGY SAVINGS & INSTALLED COSTS
FOR VARIOUS DEVICES

DEVICE	INSTALLED COST	AVERAGE ENERGY SAVINGS (BTU/Degree Day/Year)
AVD	$210	2,280
VR	$ 66	1,710
Derating	$106	1,900
Outside Air	$ 65	760
IID	$120	(19,200)*

*Energy savings for IID's are expressed as BTU/day of burner off time/year. Burner off time is calculated as the total time period over a year for which the main burner is not operating. It is determined as the number of days a furnace is off during summer shutdown plus the accumulation of time through winter months between burner cycles.

IX. RECOMMENDATIONS

Research work that has been presented represents considerable investment of time and money by many agencies. Several of the programs, noteably NBS studies of oil burners and AGA and utility work on gas furnaces are continuing projects. The presence of this data leads to the recommendation that further tests under the original plan of this Task Order are not recommended. In order to obtain significant refinements in the available data, a great deal of time and money is necessary. It is recommended that a follow-up study be directed at appraising the State of the Art of these studies at a future date.

Data from the 1977-1978 heating season is just beginning to be evaluated and should be available by October 1978. Several evaluation programs will continue through the 1978-1979 heating season and data should be available by October 1979. As this data becomes available to quantify the effects of the most important parameters regarding energy savings for different buildings, heating systems, and geographic locations, a supplemental contract could be used to put this information in an easy to use format for use in retrofit energy conservation planning at individual Army facilities.

Continuing work on standards at national and local levels will be moving at a rapid pace over the next several months. A supplemental study could include an updating of the status of various codes. Such a supplemental study could be achieved at a moderately low cost since the contractor has established contacts with persons conducting these programs.

The Corps of Engineers may wish to utilize the expertise developed under this contract to provide instruction for Army personnel involved in inspection and approval of any contracts to install these energy saving devices.

It is recommended that individual Army units consider the potential benefits of these devices and that Local Code Authorities be contacted regarding their use in each particular case.

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